Document ID: EDF-ER-200
INEEL/EXT-2000-00821
Revision ID: 0
Effective Date: September 2000

Engineering Design File

Metals Analysis of Selected OU 1-07B Groundwater Monitoring Wells

Prepared for:
U.S. Department of Energy
Idaho Operations Office
Idaho Falls, Idaho

INEEL
Idaho National Engineering & Environmental Laboratory
BECHTEL BWXT IDAHO, LLC

Form 412.14
10/05/99
Rev. 02

431.02
08/12/98
Rev. 06

ENGINEERING DESIGN FILE

Functional File No. INEEL/EXT-2000-00821
EDF No. EDF-ER-200

1. Project File No. 6223-AD 2. Project/Task WAG 1 OU 1-07B ROD Amendment

3. Subtask

4. Title: Metals Analysis of Selected OU 1-07B Groundwater Monitoring Wells

5. Summary: Contaminants of concern that will be addressed by the ISB treatment system for the Test Area North Operable Unit 1-07B contaminated groundwater plume are the volatile organic compounds trichloroethene, cis-dichloroethene, trans-dichloroethene, and tetrachloroethene. The proposed cleanup strategy for the most contaminated portion of the plume is enhanced in situ bioremediation (ISB). One of the concerns with implementation of ISB that has been raised by the Idaho Department of Environmental Quality and the Environmental Protection Agency is the possible mobilization of metals such as chromium, nickel, and lead from the historically injected waste solids into the aqueous phase. To determine if metals are mobilized from the solid phase and transported downgradient as a result of ISB, groundwater samples have been collected and analyzed for metals according to the Contract Laboratory Program metals list. Based on the results of the sampling and analysis activity, metal contaminants associated with injected waste solids such as lead and chromium are not mobilized as a result of ISB. Metals that are present naturally as components of Snake River Plain basalt such as iron, manganese, barium, and zinc are mobilized into the aqueous phase as a result of ISB. However, these naturally occurring metals are not transported outside of the ISB treatment zone. Once ISB is terminated, dissolved metals such as iron, manganese, barium, and zinc will precipitate out of the aqueous phase. Periodic sampling for metals is recommended to ensure that these metals are not transported outside of the ISB treatment zone. Also, use of a 0.45-μm filter is recommended to obtain accurate analysis of dissolved chromium, nickel, and lead.

6. Distribution (complete package):

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author	A	Lee O. Nelson	Lee O. Nelson	9/20/00
Independent Verification	A	Lance N. Peterson	L N Peterson	9/21/00
Requestor	R	Joseph S. Rothermel	Joe Rothermel	9/21/00
Principal Engineer	R	Kent S. Sorenson	Kent Sorenson	9/21/00
Project Engineer	R	Jerry P. Shea	Jerry P. Shea	9/25/00

CONTENTS

FIGURES

TABLES

ACRONYMS

CLP	Contract Laboratory Program
ISB	in situ bioremediation
MCL	maximum concentration limit
ND	nondetect
OU	Operable Unit
RPD	relative percent difference
TAN	Test Area North
TSF	Technical Support Facility

Metals Analysis of Selected OU 1-07B Groundwater Monitoring Wells

1. INTRODUCTION

Enhanced in situ bioremediation (ISB) is the proposed remedy for cleanup of Operable Unit (OU) 1-07B groundwater that is contaminated with trichloroethene, tetrachloroethene, cis-1,2-dichloroethene, and trans-1,2-dichloroethene. In order to implement ISB, an amendment (sodium lactate or other suitable electron donor) is injected into the groundwater to promote the growth of naturally occurring bacteria that break down the contaminants into harmless by-products such as ethene, ethane, carbon dioxide, chloride and water. The changes to the groundwater resulting from ISB include a decrease in pH, a decreased oxidation-reduction potential, an increased concentration of carbon dioxide species, and an increased concentration of organic compounds.

There is concern that metals may be mobilized into Test Area North (TAN) groundwater as a result of ISB. Sampling and analysis of selected monitoring wells has been conducted per Idaho Department of Environmental Quality and Environmental Protection Agency request to determine if the concentration of metals in the groundwater has increased during the ISB field evaluation. The target analytes of this sampling and analysis activity consist of the Contract Laboratory Program (CLP) metals list as shown in Appendix A. Metals analyses were completed per SW-846 protocol.

2. POSSIBLE SOURCES OF METALS IN TAN GROUNDWATER

Three possible sources of metals in TAN groundwater have been investigated. The first possible source of metal contaminants considered is trace contaminants associated with the sodium lactate injections. Sodium lactate contains trace quantities of metals as shown in Appendix B. Many of these trace metals are present in the sodium lactate at concentrations greater than the applicable maximum concentration limit (MCL). The State of Idaho has granted permission to inject sodium lactate into the groundwater to support the ISB field evaluation. Modeling has predicted that the trace metals in the sodium lactate do not present a long-term risk to groundwater quality. Groundwater-monitoring data are used to verify the model predictions.

Sodium lactate to be injected into the groundwater is procured as a 60% (wt/wt) solution (in water). The concentrations of lead, nickel, chromium, and barium in an unfiltered sample of Purac America 60% sodium lactate solution are 131, 160, and 750, and 17.4 μg/L, respectively (see Appendix B). The 60% sodium lactate solution has a viscosity of 150 cP and a density of 1.33 g/ml at 20°C. Early sodium lactate injections were completed with a 60% solution and the resulting density driven flow caused an uneven distribution of sodium lactate in the aquifer. By August 1999, the concentrations of sodium lactate were the highest in well TAN-26, the deepest well located within the ISB treatment zone (Sorenson et al. 2000).

Dilution of the sodium lactate from a 60% solution to a 3–6% solution reduces the density to 1.015–1.03 g/ml, respectively. The viscosity also is reduced to less than 5 cP as a result of sodium lactate dilution. This dilution facilitates dispersion of the sodium lactate into the aquifer and dilutes the concentrations of trace metals present in the injected fluid. Sodium lactate is injected into well Technical Support Facility-05 (TSF-05). The concentrations of lead, nickel, chromium, and barium in various sodium lactate solutions are in Table 1. The sodium lactate injection schedule used over the timeframe associated with the metals sampling and analysis activity is in Table 2.

Table 1. Concentrations of lead, nickel, chromium, and barium in sodium lactate solutions.

Sodium Lactate Solution	Lead (µg/L)	Nickel (µg/L)	Chromium (µg/L)	Barium (µg/L)
3% Sodium Lactate	5.25	7.9	37.5	0.87
6% Sodium Lactate	10.5	15.8	75	1.74
60% Lactate	105	158	750	17.4

Table 2. ISB amendment injection schedule during the sampling and analysis activity.

Injection Date	Volume of 60% Sodium Lactate Solution Injected (gal)	Volume of Dilution Water Injected (gal)	Concentration of Sodium Lactate Injected (%)
September 8, 1999	330	6,270	3
February 8, 2000	660	12,540	3
March 30, 2000	660	12,540	3
May 15, 2000	1320	11,880	6

The second possible source of metal contaminants is the dissolution of metals from subsurface materials such as previously injected waste solids or Snake River Plain basalt. The assumed composition of both historically injected waste solids (Rothermel 1998) and Snake River Plain basalt (Knobel et al. 1995) is in Table 3. The assumed composition of historically injected waste solids is based on the composition of solids removed from well TSF-05. Nearly all CLP list metals are found in both the injected waste solids and the basalt. However, the concentrations of metals detected in each material are variable. For example, the concentrations of lead and zinc are much higher in the injected waste solids as compared to the basalt. On the other hand, barium, calcium, iron, and manganese are more highly concentrated in the basalt. Chromium and nickel are found in relatively the same concentrations in both the basalt and the waste solids.

Metals dissolution is assumed to occur by one of two mechanisms: carbonate dissolution or reduction of insoluble metals to soluble species. The majority of calcium in the aquifer is formed by the precipitation of calcium carbonate ($CaCO_3$). As carbon dioxide concentrations are significantly increased during ISB, the equilibrium of this reaction is disturbed and the calcite is dissolved (Sorenson et al. 2000). Barium (a divalent cation like calcium) is also a component of the TAN basalt and also is dissolved by elevated levels of carbon dioxide. Since elevated levels of carbon dioxide dissolve calcium and barium carbonate, the concentrations of these metals in the aqueous phase are expected to increase when ISB is active and decrease simultaneously when ISB is terminated. The oxidation states of iron, manganese, and zinc are expected to be reduced to soluble species and dissolved into the groundwater as a result of the ISB-induced change in the groundwater oxidation-reduction potential. The concentrations of these dissolved metals in the aqueous phase are assumed to decrease to baseline levels once ISB is terminated and the chemical conditions in the groundwater return to normal.

The third possible source of metal contaminants is leachate from sampling equipment (pumps), cross contamination, variable concentrations from entrained solids, and other unknown factors. These types of sources occasionally produce anomalous groundwater monitoring data. Anomalous sampling and analysis data for monitoring wells in the vicinity of TAN is in Appendix C. Occasionally, the concentrations of lead and chromium increase to levels above the MCL and then decrease to background levels.

Table 3. Concentration ranges of metals detected in historically injected waste solids and Snake River Plain basalt.

	Historically Injected Waste Solids (mg/L)		Snake River Plain Basalt (mg/L)	
Analyte	min	max	min	max
Ba	119	147	162	593
Ca	22000	24400	90000	110000
Cr	138	157	107	380
Fe	39100	110000	100000	150000
Pb	75	89	ND	8
Mn	289	649	17000	23000
Ni	52	70	28	105
Zn	916	1190	74	158

3. SAMPLE RESULTS

Ten monitoring locations were sampled and analyzed for metals in November 1999, January 2000, and February 2000: wells TAN-25, TAN-26, TAN-37A, TAN-37B, TAN-28, TAN-30A, TAN-31, TAN-D2, TAN-10A, and TAN-27. These initial samples were not filtered. Additional samples were collected in May and June 2000 from three locations: wells TAN-25, TAN-26, and TAN-31. Both filtered and unfiltered samples were collected in the May and June sampling and analysis activity. The locations of the groundwater monitoring wells sampled in support of this activity are shown in relation to the contaminant plume in Figure 1.

Analytical results of unfiltered groundwater samples are in Table 4 for lead, nickel, and chromium. The results of filtered groundwater sampling and analysis for these same three metals are in Table 5. Figure 2 provides a graphical comparison of the filtered and unfiltered sample results. The concentrations of lead, nickel, and chromium detected in unfiltered groundwater samples ranged from 8 to 64.6 μg/L, nondetect (ND) to 92.5μg/L, and ND to 106 μg/L respectively. The concentrations of all three of these metals decreased to low levels in the June 2000 samples. The relative percent difference (RPD) of duplicate unfiltered samples taken in May 2000 was 36%, 85%, and 144% for lead, nickel, and chromium respectively.

Because of the high RPDs observed in the concentrations of lead, nickel and chromium in unfiltered samples, some of the May and June 2000 samples were filtered with a 0.45-μm filter. The concentrations of lead, nickel, and chromium detected in filtered samples were all less than the applicable MCL (see Table 5). The RPDs of duplicate filtered samples were 36% for lead and 4.5% for nickel. Chromium was not detected in June 2000 duplicate filtered samples.

The concentrations of calcium, barium, iron, manganese, and zinc before January 1999 (when ISB testing resumed) are shown in Table 6. The concentrations of these same elements after ISB testing was initiated are shown in Table 7. A graphical representation of the metals concentration before and after ISB is shown in Figure 3 for well TAN-25 and in Figure 4 for wells TAN-25, TAN-26, and TAN-31. A complete listing of historical groundwater monitoring data is available in the FY 99 Groundwater Monitoring Annual Report (Bukowski 2000). A complete list of the groundwater sampling and analysis results obtained for this investigation is in Appendix D. The concentration of barium detected in groundwater samples taken from well TAN-25 and TAN-26 occasionally exceeded the MCL after ISB injections resumed. Also, the concentrations of iron, manganese, and zinc detected in groundwater samples increased to levels greater than the applicable secondary MCLs after ISB injections resumed. To

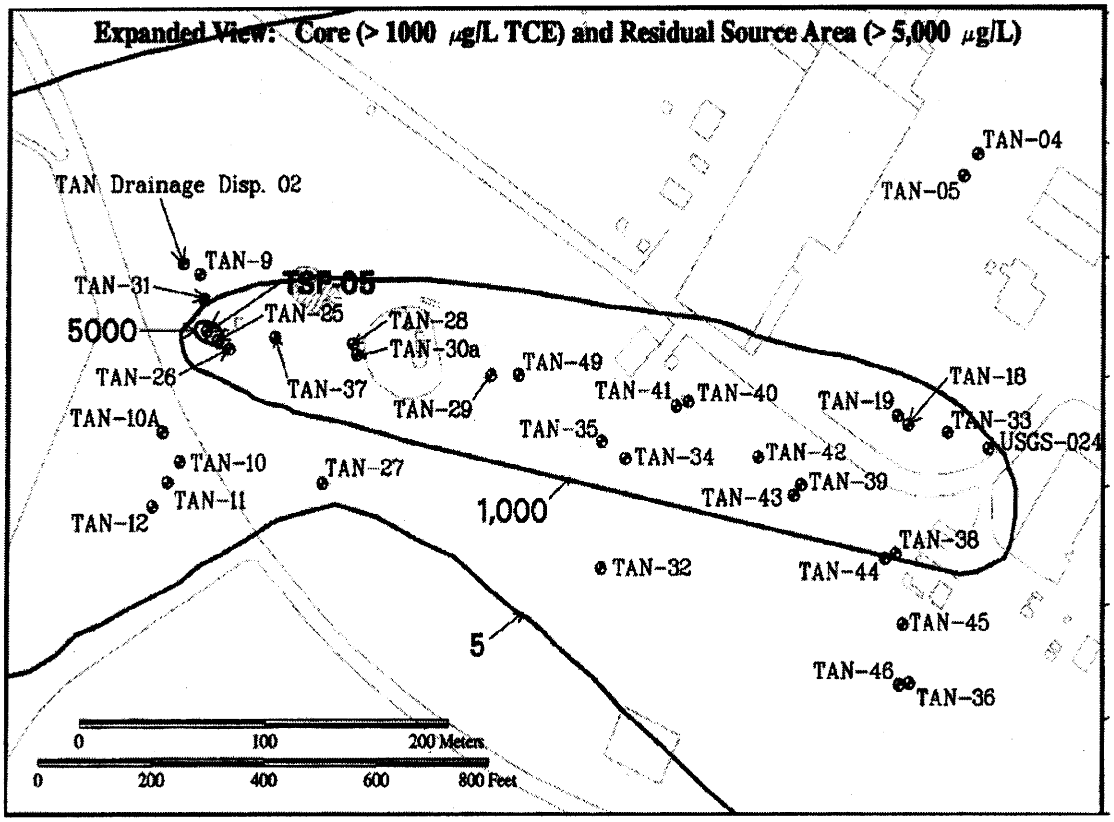


Figure 1. Expanded view of the Test Area North contaminated groundwater plume in relation to groundwater monitoring wells. The isopleths are for trichloroethene concentrations of 5 ppb, 1,000 ppb, and 5,000 ppb.

Table 4. Concentrations of lead, nickel, and chromium detected in unfiltered TAN groundwater samples during ISB testing.

		Concentration (µg/L)					
Well	Analyte	November 1999	January 2000	February 2000	April 2000	May 2000	June 2000
TAN-25	Pb	64.6	27.1	23.3	33.8	22.0	8
TAN-25	Ni	44.6	ND	ND	34.8	92.5	29
TAN-25	Cr	ND	ND	14.0	14.2	106.0	10
TAN-26	Pb	8.4	8.9	3.0	ND	4.9[b] / 3.4[b]	5
TAN-26	Ni	46.9	ND	ND	23	47[b] / 19.9[b]	18
TAN-26	Cr	ND	ND	ND	48.8	ND[b] / 30.6[b]	ND
TAN-28	Cr	ND	ND	13.1[b] / ND[b]	ND	31	ND
TAN-31	Pb	6.6	ND	ND	ND	4.2	5

a. The "N" indicates that the overall mass recovery for this element was outside of the 80% of 120% limits.

b. These are duplicate samples. ND represents a nondetect.

Table 5. Concentration of lead, nickel, and chromium detected in filtered TAN groundwater samples during ISB testing.

		Concentration (µg/L)		
Well	Analyte	May 2000	June 2000	MCL (µg/L)
TAN-25	Pb	6.1	4.3 / 3[a]	15
TAN-25	Ni	72.1	17.5 / 18.3[a]	NA[c]
TAN-25	Cr	94.2	ND / ND[a,b]	100
TAN-26	Pb	5.4	3.8	15
TAN-26	Ni	19.4	21.0	NA[c]
TAN-31	Pb	3.0	3.0	15
TAN-31	Ni	7.3	5.6	NA[c]
TAN-31	Cr	6.2	ND[b]	100

a. Duplicate samples.

b. ND represents a nondetect.

c. NA indicates that there is no MCL for this metal.

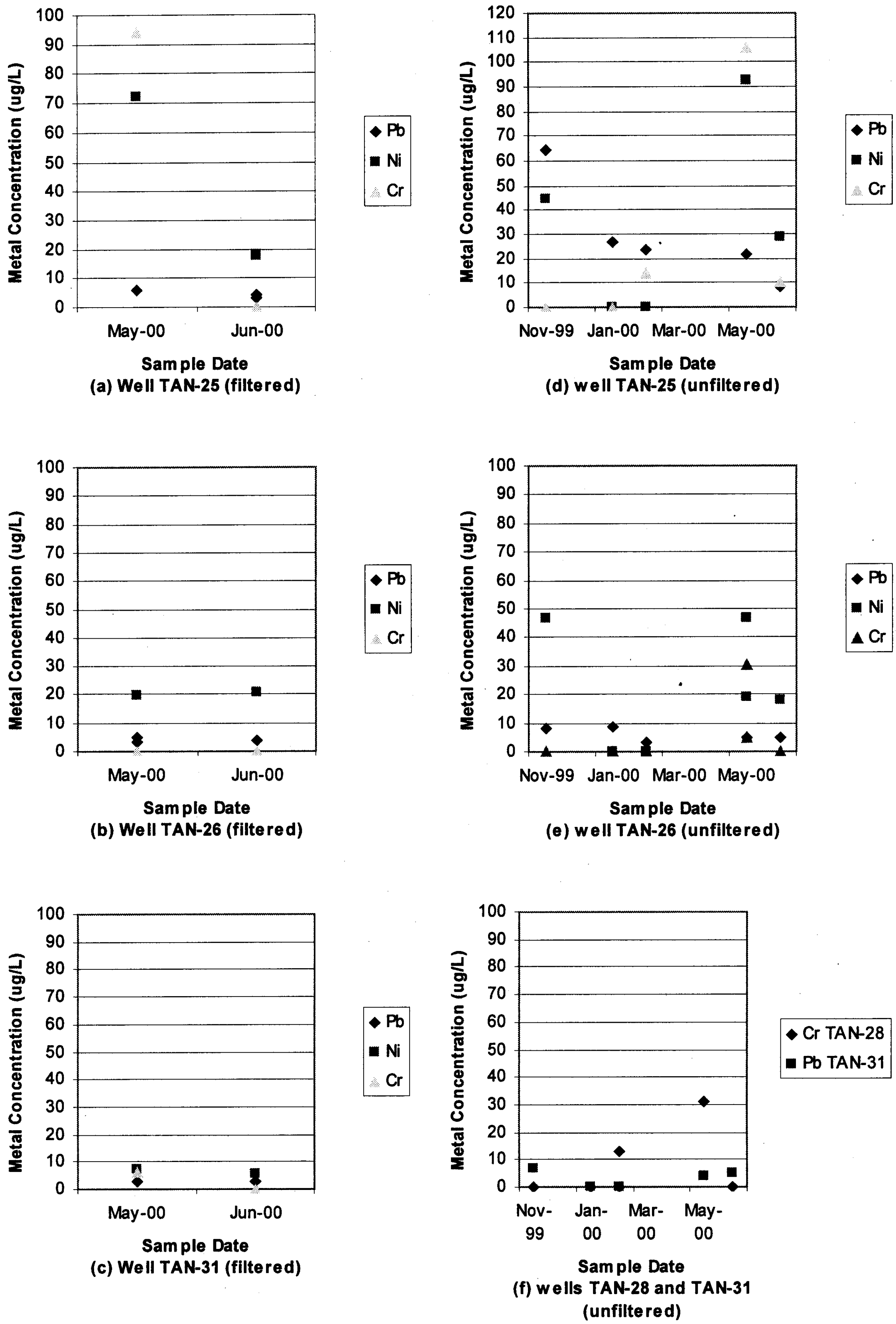


Figure 2. Plot of the concentration of metals detected in selected TAN monitoring wells. The sample data shown in (a), (b), and (c) were for filtered samples. The concentrations of metals in unfiltered samples from the same wells are in (d), (e), and (f).

Table 6. Concentrations of barium, iron, manganese, and zinc in selected groundwater monitoring wells before ISB tests were initiated.

		Concentration (µg/L)				
Well	Analyte	1993	1995	1996	1997	Regulatory Limit
TAN-25	Ca	62300	61200	45300	59000	NA
TAN-25	Ba	254	210	169	209	2000[1]
TAN-25	Fe	*478*	*775*	89	226	300[2]
TAN-25	Mn	*200*	*201*	*101*	43	50[2]
TAN-25	Zn	137	80	15	9	5000[2]
TAN-26	Ca	74700	73300	ns	67100	NA
TAN-26	Ba	136	142	ns	172	2000[1]
TAN-26	Fe	*719*	*3590*	ns	ND	300[2]
TAN-26	Mn	*54*	ND	ns	ND	50[2]
TAN-26	Zn	51	ND	ns	426	5000[2]
TAN-31	Ca	ns	ns	20000	ns	NA
TAN-31	Ba	ns	ns	79	ns	2000[1]
TAN-31	Fe	ns	ns	47	ns	300[2]
TAN-31	Mn	ns	ns	16	ns	50[2]
TAN-31	Zn	ns	ns	143	ns	5000[2]
TAN-27	Ca	ns	ns	82600	72500	NA
TAN-27	Ba	ns	ns	171	161	2000[1]
TAN-27	Fe	ns	ns	*970*	242	300[2]
TAN-27	Mn	ns	ns	*55*	20	50[2]
TAN-27	Zn	ns	ns	1650	1300	5000[2]

1. Maximum Concentration Limit (MCL)
2. Secondary MCL
NA. There is no MCL for this component
ND. The element was not detected in the sample
NS. No groundwater samples were taken at the indicated time.
Italicized text indicates that the concentration exceeds the secondary MCL.

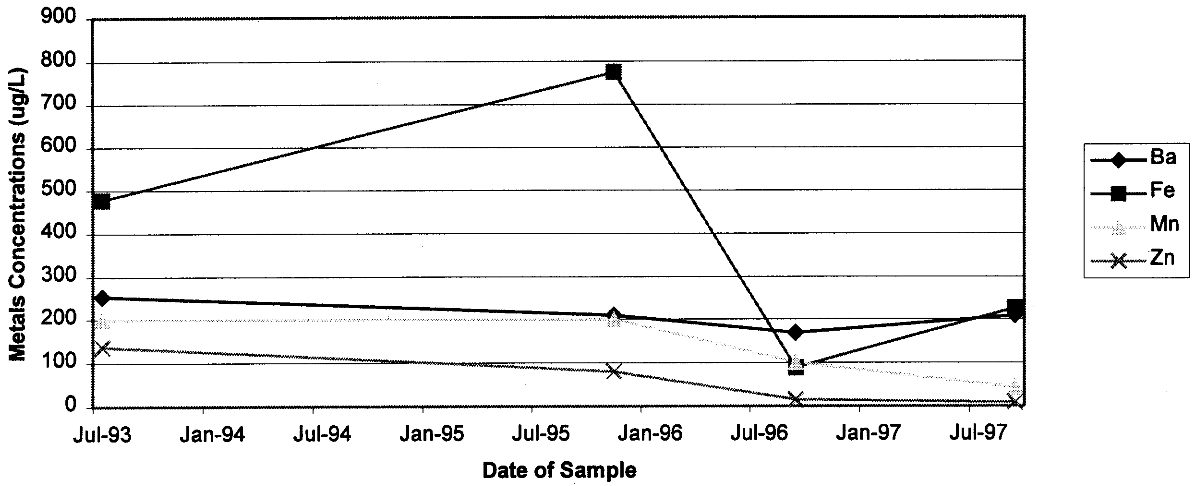


Figure 3. Concentrations of barium, iron, manganese, and zinc in well TAN-25 before ISB tests began.

Table 7. Concentrations of barium, iron, manganese, and zinc in selected groundwater monitoring wells after ISB tests were initiated.

		Concentration (µg/L)						
Well	Analyte	November 1999	January 2000	February 2000	April 2000	May 2000	June 2000	Regulatory Limit
TAN-25	Ca	100000	87300	187000	161000	292000	156000	NA
TAN-25	Ba	599	427	1170	1030	**2120**	1000	2000[1]
TAN-25	Fe	*6930*	*4570*	*15100*	*20300*	*27900*	*11700*	300[2]
TAN-25	Mn	*1060*	*810*	*2050*	*2380*	*3640*	*1720*	50[2]
TAN-25	Zn	2360	1580	6170	4660	4610	1110	5000[2]
TAN-26	Ca	300000	239000	199000	16500	157000	160000	NA
TAN-26	Ba	**3790**	**2890**	**2520**	1920	1960	1890	2000[1]
TAN-26	Fe	*27600*	*22700*	*19900*	*16300*	*16000*	*15200*	300[2]
TAN-26	Mn	*7470*	*5020*	*4360*	*3560*	*3510*	*3420*	50[2]
TAN-26	Zn	*6780*	*5590*	3100	2530	2230	2280	5000[2]
TAN-31	Ca	91100	87300	160000	142000	207000	133000	NA
TAN-31	Ba	297	257	685	579	1180	546	2000[1]
TAN-31	Fe	*1590*	*1030*	*2700*	*3890*	*6140*	*3880*	300[2]
TAN-31	Mn	*650*	*633*	*1360*	*1200*	*1980*	*1110*	50[2]
TAN-31	Zn	1870	723	2790	2410	4510	926	5000[2]
TAN-27	Ca	78900	87400	81000	79600	NS	NS	NA
TAN-27	Ba	66	169	169	164	NS	NS	2000[1]
TAN-27	Fe	300	107	77	59	NS	NS	300[2]
TAN-27	Mn	5.3	5.8	5.3	5	NS	NS	50[2]
TAN-27	Zn	399	391	397	399	NS	NS	5000[2]

NA. There is no MCL for this component
NS. No groundwater samples were taken at the indicated time.
1. This is the MCL for the indicated element.
2. This is the secondary MCL for the indicated element.
Bold print indicates that the concentration of this element exceeds the MCL.
Italic print indicates that the concentration of this element exceeds the secondary MCL.

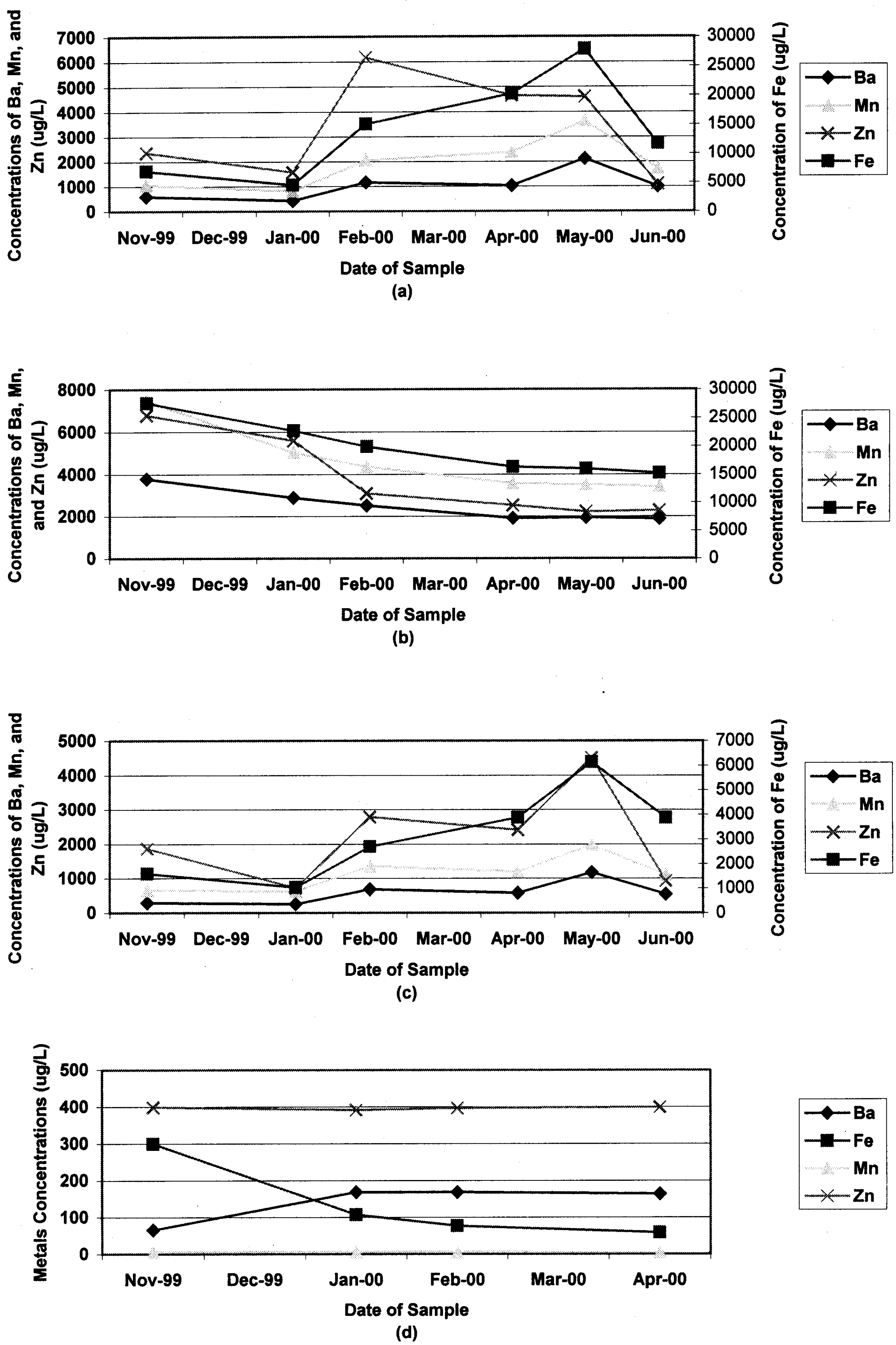
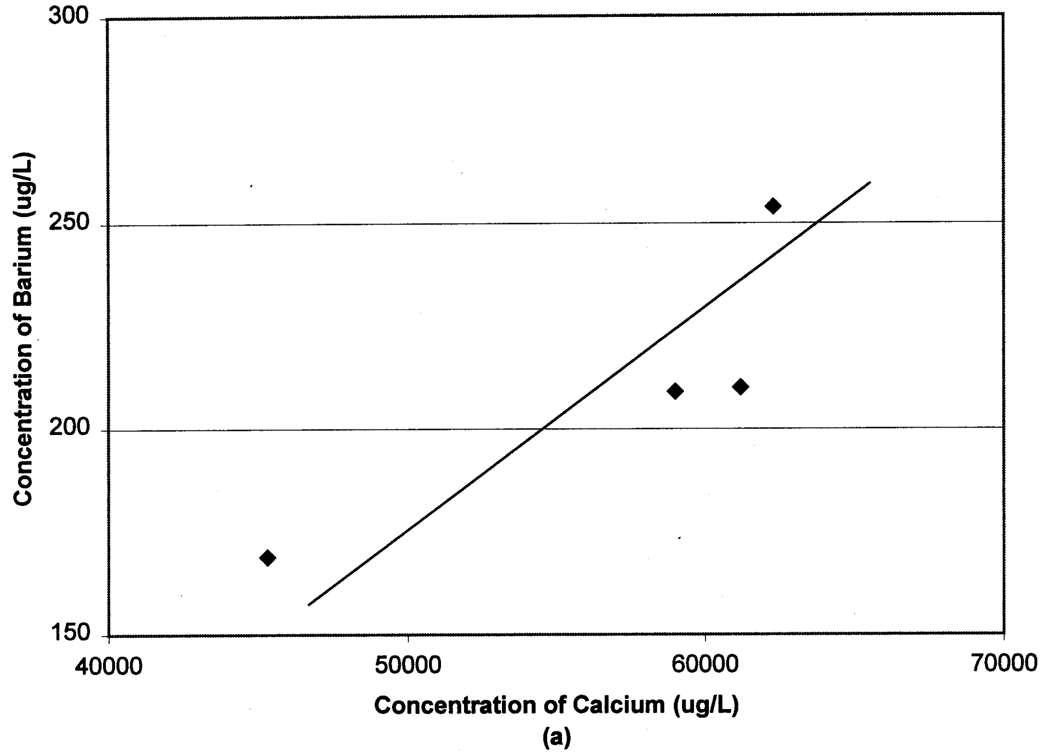


Figure 4. Plot of barium, iron, manganese, and zinc detected in groundwater samples collected in well (a) TAN-25, (b) TAN-26, (c) TAN-31, and (d) TAN-27 after ISB testing was initiated.



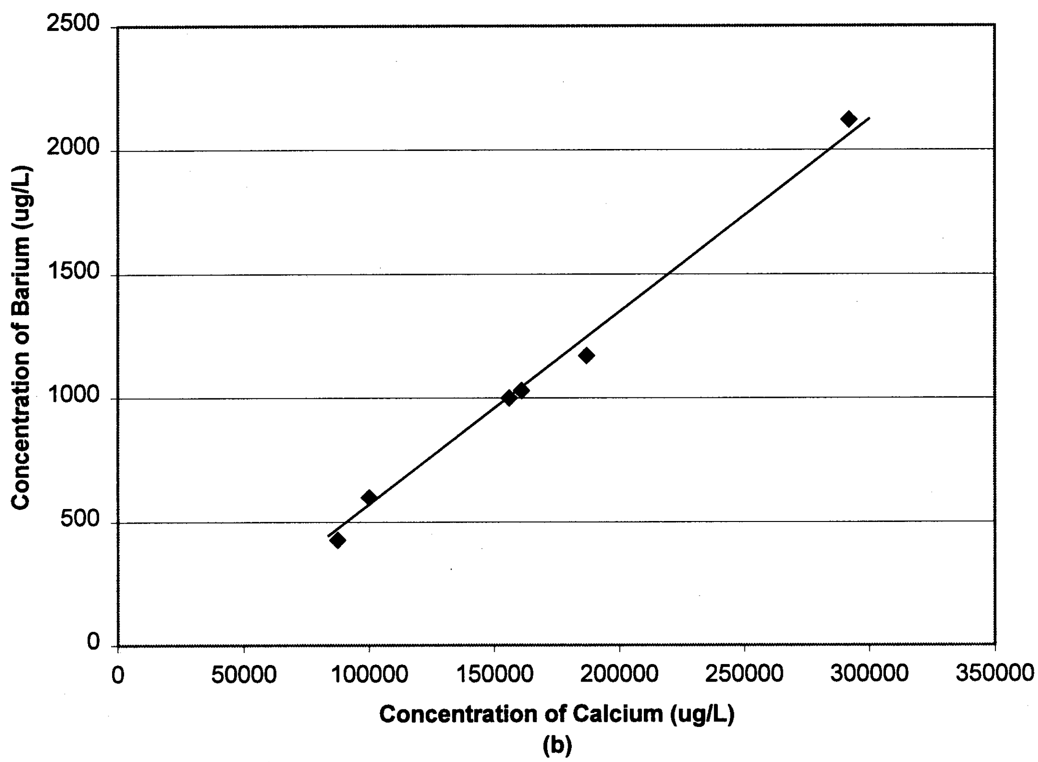


Figure 5. Plots of calcium (abscissa) and barium (ordinate) concentrations in well TAN-25 (a) before and (b) after testing of ISB was initiated. The correlation coefficients before and after ISB testing began are 0.89 and 0.99, respectively.

illustrate the correlation between calcium and barium concentrations, a plot of the calcium concentration (abscissa) and the barium concentration (ordinate) detected in well TAN-25 before and after ISB injections are in Figure 4. The correlation coefficients of calcium and barium concentrations before and after ISB injections are 0.89 and 0.99, respectively.

4. DISCUSSION

The purpose of this sampling and analysis activity was to determine if metals are mobilized into TAN groundwater as a result of ISB. Three possible sources of metal mobilization into the groundwater were investigated and compared to the results of the groundwater sampling and analysis activity. The results indicated that lead, nickel, and chromium did not exceed the applicable MCLs and do not appear to be mobilized into the aqueous phase as a result of ISB. However, other metals such as calcium, barium, iron, manganese, and zinc appear to be mobilized into the aqueous phase as a result of ISB. The concentrations of all metals in TAN groundwater are expected to be below the applicable MCLs once ISB is complete. A discussion concerning these results is included in the following paragraphs.

4.1 Lead, Nickel, and Chrome

Trace quantities of lead, nickel, and chromium in sodium lactate do not introduce contaminants to the aqueous phase of the groundwater at levels that exceed the applicable MCLs. For example, May 2000 samples (see Table 5) were taken from well TAN-25 four days after sodium lactate was injected into the groundwater. This sample contained relatively high concentrations of nickel and chromium, but not at concentrations that exceeded the MCL. The concentration of nickel and chromium in the June 2000 sample dropped significantly from the May 2000 sample and are close to baseline levels of ND to 8 μg/L (Bukowski 2000). Other trace metals present in the sodium lactate (such as lead) were not detected at high concentrations in either the May or June sample. Hence, the kinetics of nickel and chromium removal from the aqueous phase of the groundwater appears to be slower than the removal kinetics of other trace metals present in the sodium lactate.

Variable solids content caused high RPDs for lead, chromium, and nickel concentrations in duplicate unfiltered samples (see Table 4). As a result, the metals concentrations detected in unfiltered samples are not representative of the metals concentrations in groundwater. The solids content in unfiltered samples is believed to have caused the November 1999, January 2000, and February 2000 anomalous results.

Duplicate filtered groundwater samples from well TAN-25 had much lower RPDs than unfiltered duplicate samples (see Tables 4 and 5). Also, the concentration of lead was much lower in the filtered sample as compared to the unfiltered sample. Other CLP list metals that were removed by the filter were aluminum, chromium, copper, and nickel. Hence, it appears that the solids collected by the filter during May 2000 groundwater sampling consisted of lead, chromium, nickel, aluminum, and copper.

The concentrations of both lead and chromium in filtered groundwater samples were lower than the applicable MCLs. High levels of lead were detected in some of the unfiltered samples, but these anomalous readings were not caused by ISB and have returned to baseline levels during ISB testing. In order to ensure that sampling and analysis results are representative of the concentration of dissolved lead, nickel, and chromium in groundwater, it is necessary to filter samples with a 0.45-μm filter.

4.2 Barium, Calcium, Iron, Manganese, and Zinc

The concentrations of barium, calcium, iron, manganese, and zinc increased by nearly an order of magnitude when ISB injections resumed (see Table 6 and 7) and they have remained at relatively high levels during ISB testing. The high concentrations of these elements are believed to be caused by dissolution of basalt by carbonate dissolution (Ba, Ca, Fe, Mn, and Zn) and, as a result, to changes in the oxidation-reduction potential (Fe^{3+} to Fe^{2+}). The concentrations of the metals that are affected by ISB correlate rather strongly when ISB is active. For example, the correlation coefficient between calcium and barium increased from 0.89 to 0.99 once ISB testing began, which indicates that they are likely dissolved by the same mechanism.

Changes in the zinc concentrations do not correlate quite as well as the other metals that are affected by ISB. This is due to an additional source of zinc contamination. Several treatment facilities have been in operation within the area of contamination. Some of these operations have involved extraction of groundwater, treatment of groundwater at the surface to remove contaminants, and reinjection of the groundwater. Piping and process equipment are typically fabricated from galvanized pipe. This pipe provides an additional source of zinc contamination and may be the reason that the zinc concentrations do not correlate as well as barium, calcium, iron, and manganese.

The concentration of barium exceeded the MCL in well TAN-25 only in the May 2000 sample (four days after a sodium lactate injection) and decreased by approximately 50% in the June 2000 sample. All other samples from well TAN-25 had concentrations of barium below the MCL. High concentrations of barium are only expected to occur shortly after sodium lactate injections as a result of increased biological activity.

The concentration of barium in well TAN-26 exceeded the MCL in November 1999, January 2000, and February 2000, but it has been steadily decreasing throughout the sampling and analysis activity. The high levels of barium initially observed in well TAN-26 are believed to be caused by a residual buildup of sodium lactate from previous highly concentrated sodium lactate injections. As the concentration of sodium lactate in well TAN-26 decreases, the concentration of carbon dioxide in well TAN-26 will decrease. Lower carbon dioxide concentrations in well TAN-26 will result in lower concentrations of dissolved metals. Once ISB is completed, the concentrations of barium, calcium, iron, manganese, and zinc are expected to return to baseline levels and will be less than the applicable MCL or secondary MCL.

5. CONCLUSIONS

1. Metals have not become contaminants of concern for the TAN groundwater cleanup project as a result of ISB.

2. The concentrations of metals in the groundwater do not exceed MCLs as a result of trace metal contaminants associated with sodium lactate injections.

3. Lead and chromium do not dissolve from historically injected waste solids into the groundwater as a result of ISB.

4. Groundwater samples should be filtered with a 0.45-µm filter to obtain lead, chromium, and nickel results that are representative of the concentrations of these metals in the groundwater.

5. Variability of lead, chromium, and nickel concentrations in unfiltered groundwater samples is caused by variable concentrations of solids in groundwater monitoring samples.

6. The high concentrations of barium, iron, manganese, and zinc are caused by dissolution of these elements from the basalt as a result of ISB induced changes to the groundwater chemistry.

7. The concentrations of all metals in TAN groundwater are expected to be below the applicable MCLs at the end of the remediation timeframe.

6. REFERENCES

Bukowski, J., 2000, "Fiscal Year 1999 Groundwater Monitoring Annual Report Test Area North, Operable Unit 1-07B," INEEL-99-01255, Rev. 0.

Knobel, L. L. et al., 1995, "Chemical Composition of Selected Core Samples, Idaho National Engineering Laboratory, Idaho," USGS, DOE/ID-22126.

Rothermel, J. S., 1998, letter to A. E. Jantz dated December 15, 1998, "TSF-05 Sludge Sample Results—part 2," 273:01:028-98.

Sorenson, K. S. et al., 2000, "Field Evaluation Report of Enhanced In Situ Bioremediation, Test Area North, Operable Unit 1-07B," INEEL/EXT-2000-00258, Rev. 0, July.

Appendix A

Metals CLP Target Analyte List

Appendix A

Metals CLP Target Analyte List

Metals CLP Target Analyte List

Aluminum	Magnesium
Antimony	Manganese
Arsenic	Mercury
Barium	Nickel
Beryllium	Potassium
Cadmium	Selenium
Calcium	Silver
Chromium	Sodium
Cobalt	Thallium
Copper	Vanadium
Iron	Zinc
Lead	

Appendix B

Concentration of Trace Metals in 60% Sodium Lactate Samples

Appendix B

Concentration of Trace Metals in 60% Sodium Lactate Samples

	Sodium Lactate Sample Results (µg/L)									
CLP Analyte	Ashland 1997		Purac 1997		Purac 7/2000		Purac 7/2000		Purac 7/2000	
Aluminum	1040	B	1490	B	4800	U	4600	U	4900	U
Antimony	205	B	206	B	950	U	930	U	970	U
Arsenic	539		430		480	U	460	U	490	U
Barium	353	B	17.4	B	480	U	460	U	490	U
Beryllium	40	U	40	U	480	U	460	U	490	U
Cadmium	18.5	B	18.4	B	480	U	460	U	490	U
Calcium	610	U	610	U	4800	U	4600	U	4900	U
Chromium	412		749		1600		460	U	2800	
Cobalt	110	U	170	B	480	U	460	U	490	U
Copper	80	U	125	B	480	U	460	U	490	U
Iron	1460		1180		6800	B	4600	U	12900	
Lead	131		105		290	U	290	U	290	U
Magnesium	670	U	670	U	4800	U	4600	U	4900	U
Manganese	40	U	85.3	B	480	U	460	U	490	U
Mercury	2	U	2	U	100	U	100	U	90	U
Nickel	162	B	158	B	810	B	460	U	1500	B
Potassium	173000		88700		94500	B	83400	B	97400	B
Selenium	1630		1540		670		610		830	
Silver	16.1	B	12.9	B	480	U	460	U	490	U
Sodium	1.3X108		1.3X108		1.15E+08		1.17E+08		1.16E+08	
Thallium	400	U	40	U	950	U	930	U	970	U
Vanadium	120	U	120	U	480	U	460	U	490	U
Zinc	124	N	60	U	480	U	460	U	490	U

U—Indicates that the specified element was not detected at concentrations exceeding the given method detection limit. B—Indicates that the element was detected at concentrations less than the given method detection limit, but above the instrument detection limit.

Appendix C

Anomalous Metals Data from Selected Groundwater Monitoring Wells

Appendix C

Anomalous Metals Data from Selected Groundwater Monitoring Wells

Well	Typical/Maximum Pb (µg/L)	Typical/Maximum Ni (µg/L)	Typical/Maximum Cr (µg/L)
USGS-24	ND / 13.5	ND / <11	ND / <7
USGS-25	—	—	ND / 15
USGS-26	ND / 8	—	ND / 10
TAN-27	ND / 7.4	49.2	ND / 8.7
INEL-1	—	ND / 12	—
USGS-121	—	<10 / 20	—
USGS-015	<1 / 16	2 / 15	—
USGS-097	1 / 2200	1 / 8	—
ANP-02	<5 / 18	—	—
USGS-011	1 / 18	—	—
USGS-041	1 / 24	—	—
USGS-065	<5 / 65	—	—
USGS-086	<2 / 30	—	—
USGS-108	2 / 16	—	—
USGS-110	<5 / 20	—	—

Appendix D

Groundwater Monitoring Data

Appendix D
Groundwater Monitoring Data

Groundwater monitoring data given in units of ug/L

Analyte	MCL	May-00 BLANK	Jun-00 BLANK	Nov-99 TAN-10A Unfiltered	Jan-00 TAN-10A Unfiltered	Feb-00 TAN-10A Unfiltered	Apr-00 TAN-10A Unfiltered	Nov-99 TAN-25 Unfiltered	Jan-00 TAN-25 Unfiltered	Feb-00 TAN-25 Unfiltered	Apr-00 TAN-25 Unfiltered	May-00 TAN-25 Unfiltered
Al	200	50 U	50 U	50 U	50 U	50 U	50 U	65.5 B	50 U	51.1 B	83.2 B	211
Sb	6	10 U	10 U	5 U	10 U	10 U	10 U	5 U	10 U	10 U	10 U	10 U
As	50	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Ba	2000	5 U	5 U	206	215	218	210	599	427	1170	1030	2120
Be	4	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Cd	5	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Ca		56.7 B	288 B	73200	79200	75300	74900	100000	87300	187000	161000	292000
Cr	100	5 U	5 U	5 U	5 U	5 U	5 U	7.1 B	6.8 N	14	14.2	106
Co		5 U	5 U	5 U	5 U	5 U	5 U	7 B	5 U	7.6 B	6	15.9 B
Cu		5 U	5 U	5 U	5 U	5 U	5 U	11.2 B	5 U	328	90.1	33
Fe	300	58.4 U	50 U	508	464	209	221	6930	4570	15100	20300	27900
Pb	15	4.7 U	3 U	3 U	4.2	3 U	3 U	64.6	27.1	23.3	33.8	22
Mg		50 U	50 U	18200	20400 B	19000	18800	33800	29800 B	61500	59000 B	102000 B
Mn	50	5 U	5 U	8.9 B	8.1 B	6.2 B	5.4	1060	810	2050	2380	3640
Hg	2	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.69
Ni		5 U	5 U	5 U	5 U	5 U	8.5	44.6	27 B	34.3 B	34.8	92.5
K		200 U	200 U	3400 B	3520 B	3550 B	3430 B	10900	5610	9530	8750	12300
Se	50	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	6.2	5 U	8.5
Ag	100	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	6 B
Na		819 U	200 U	41600	46000	44500	44300	519000	431000	1200000	1080000	2520000
Tl	2	10 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U
V		5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	28.7 B
Zn	5000	7.2 U	5 U	747	621	681	955	2360	1580	6170	4660	4610

'U' Indicates that the identified element was not detected at the given concentration
'B' Indicates that the concentration of the identified element was below the MDL, but was above the instrument detection limit

Appendix D
Groundwater Monitoring Data

Groundwater monitoring data given in units of ug/L

	MCL	May-00	Jun-00 Fl	Jun-00	Jun-00	Jun-00	Nov-99	Jan-00	Feb-00	Apr-00	May-00	May-00
log no.		1101LL	4201LA	4201LL	4202LA	4202LL	12201LA	30101LA	201LA	6001LA	1201LA	1202LA
		TAN-25	TAN-25	TAN-25	TAN-25	TAN-25	TAN-26	TAN-26	TAN-26	TAN-26	TAN-26	TAN-26
Analyte		Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered
Al	200	65.1 B	83 B	80.1 B	87.8 B	50 U	52.3 B	50 U	50 U	50 U	50 U	50 U
Sb	6	10 U	10 U	10 U	10 U	10 U	5 U	10 U	10 U	10 U	10 U	10 U
As	50	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Ba	2000	2150	1000	998	1010	1010	3790	2890	2520	1920	1960	1960
Be	4	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Cd	5	5 U	5 U	5 U	5 U	5 U	5 U	5.3	5 U	5 U	5 U	5 U
Ca		291000	156000	160000	158000	157000	300000	239000	199000	165000	157000 B	155000 B
Cr	100	94.2	9.5 B	5 U	9.4 B	5 U	5 U	5 U	5 U	48.8	5 U	30.6
Co		15.2 B	5 B	5 U	5.2 B	5 U	55.9	36 B	27.4 B	19.3	17.3 B	18.7 B
Cu		5 U	15.1 B	5 U	9.4 B	5 U	5 U	5.4 B	5 U	5 U	5 U	5 U
Fe	300	28200	11700	11500	11700	11700	27600	22700	19900	16300	16000	16100
Pb	15	6.1	7.9	4.3	4.1	3 U	8.4	8.9	3	3 U	4.9	3.4
Mg		102000 B	58200 B	59500 B	58600 B	58200 B	159000	142000	127000	109000	105000 B	105000 B
Mn	50	3700	1720	1700	1720	1730	7470	5020	4360	3560	3510	3510
Hg	2	0.2 U	0.23	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Ni		72.1	28.7 B	17.5 B	28 B	18.3 B	46.9	32.5 B	24.9 B	23	19.9 B	47.2
K		12300	8760	8600	8630	8670	26100	13000	11500	10300	10800	10600
Se	50	10.1	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Ag	100	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Na		2480000	1160000	1150000	1150000	1140000	853000	867000	695000	615000	640000	635000
Tl	2	10 U	10 U	10 U	10 U	10 U	2 U	2 U	2 U	2 U	10 U	10 U
V		28.3 B	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Zn	5000	4010	1110	24	1180	213	6780	5590	3100	2530	2230	2340

'U' Indicates that the identified element was not detected at the given concentration

'B' Indicates that the concentration of the identified element was below the MDL, but was above the instrument detection limit

Appendix D
Groundwater Monitoring Data

Groundwater monitoring data given in units of ug/L

	MCL	May-00	May-00	Jun-00	Jun-00	Nov-99	Jan-00	Feb-00	Apr-00	Nov-99	Jan-00	Feb-00
log no.		1201LL	1202LL	4301LA	4301LL	13101LA	31201LA	1101LA	6901LA	12601LA	30501LA	601LA
		TAN-26	TAN-26	TAN-26	TAN-26	TAN-27	TAN-27	TAN-27	TAN-27	TAN-28	TAN-28	TAN-28
Analyte		Filtered	Filtered	Unfiltered	Filtered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered
Al	200	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Sb	6	10 U	10 U	10 U	10 U	5 U	10 U	10 U	10 U	5 U	10 U	10 U
As	50	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5.2 B	5 U	5 U
Ba	2000	1970	1970	1890	1890	65.8 B	169 B	169 B	164	235	251	255
Be	4	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Cd	5	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Ca		155000 B	156000 B	160000	161000	78900	87400	81000	79600	72200	79400	73500
Cr	100	5 U	5 U	5 U	5 U	6.5 B	10	10.4	9.9	5 U	5 U	5 U
Co		16.8 B	17.1 B	16.1 B	15.1 B	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Cu		5 U	5 U	5 U	5 U	6.7 B	5 U	5 U	5 U	5 U	5 U	5 U
Fe	300	15800	15900	15200	15300	300	107	77.1 B	58.6 B	161	182	50 U
Pb	15	5.7	5.1	4.5	3.8	3 U	3 U	3 U	3 U	3 U	3 U	3 U
Mg		104000 B	105000 B	108000	108000	19400	22100 B	20200	19900	19700	22600 B	20400
Mn	50	3490	3520	3420	3420	5.3 B	5.8 B	5.3 B	5 U	105	139	172
Hg	2	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Ni		19.4 B	19.5 B	17.6 B	21 B	66	84.2	72.1	49.2	14.8 B	10.7 B	12.6 B
K		10700	10800	10500	10400	3030 B	3500 B	3230 B	3300 B	4810 B	4760 B	4690 B
Se	50	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Ag	100	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Na		625000	634000	602000	601000	27900	32600	31400	31000	51300	61200	57700
Tl	2	10 U	10 U	10 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
V		5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Zn	5000	2520	2370	2280	2180	399	391	397	399	180	213	208

'U' Indicates that the identified element was not detected at the given concentration
'B' Indicates that the concentration of the identified element was below the MDL, but was above the instrument detection limit

Appendix D
Groundwater Monitoring Data

Groundwater monitoring data given in units of ug/L

	MCL	Feb-00	Apr-00	Nov-99	Jan-00	Feb-00	Apr-00	Nov-99	Jan-00	Feb-00	Apr-00	May-00
log no.		602LA	6401LA	12701LA	30801LA	701LA	6501LA	12801LA	30901LA	801LA	6601LA	1301LA
		TAN-28	TAN-28	TAN-30A	TAN-30A	TAN-30A	TAN-30A	TAN-31	TAN-31	TAN-31	TAN-31	TAN-31
Analyte		Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered
Al	200	50 U	50 U	50 U	50 U	50 U	50 U	124 B	50 U	50 U	50 U	50 U
Sb	6	10 U	10 U	5 U	10 U	10 U	10 U	5 U	10 U	10 U	10 U	10 U
As	50	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Ba	2000	261	254	205	220	224	227	297	257	685	579	1180
Be	4	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Cd	5	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Ca		75100	73300	78300	85100	81000	83800	91100	87300	160000	142000	207000 B
Cr	100	13.1	5 U	5 U	5 U	10.6	5 U	5 U	5 U	5 U	5 U	25.1
Co		5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Cu		5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Fe	300	106	50 U	50 U	50 U	50 U	50 U	1590	1030	2700	3890	6140
Pb	15	3 U	3 U	3 U	3 U	3 U	3 U	6.6	3.5	3 U	3 U	4.2
Mg		20700	21800	20000	23000 B	21400	22600	30200	28700 B	55500	48600	69900 B
Mn	50	176	299	6.8 B	6.4 B	6.2 B	7.7	650	633	1360	1200	1980
Hg	2	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Ni		15.1 B	6.8	6.9 B	5 U	6.6 B	5 U	10.1 B	18.1 B	5.4 B	11	31.2 B
K		4630 B	4520 B	4610 B	4930 B	4830 B	4850 B	5540	4170 B	6660	6040	8710
Se	50	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Ag	100	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Na		58400	57100	34500	38800	38000	38000	138000	111000	297000	268000	606000
Tl	2	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	10 U
V		5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Zn	5000	217	193	805	639	657	710	1870	723	2790	2410	4510

'U' Indicates that the identified element was not detected at the given concentration
'B' Indicates that the concentration of the identified element was below the MDL, but was above the instrument detection limit

Appendix D
Groundwater Monitoring Data

Groundwater monitoring data given in units of ug/L

	MCL	May-00	Jun-00	Jun-00	Nov-99	Jan-00	Feb-00	Apr-00	Nov-99	Jan-00	Jan-00	Feb-00
log no.		1301LL	4401LA	4401LL	12301LA	30201LA	301LA	6101LA	12401LA	30301LA	30302LA	401LA
		TAN-31	TAN-31	TAN-31	TAN-37A	TAN-37A	TAN-37A	TAN-37A	TAN-37B	TAN-37B	TAN-37B	TAN-37B
Analyte		Filtered	Unfiltered	Filtered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered
Al	200	50 U	58.9 B	50 U	50 U	50 U	50 U	50 U	106 B	82.5 B	69.3 B	136 B
Sb	6	10 U	10 U	10 U	5 U	10 U	10 U	10 U	5 U	10 U	10 U	10 U
As	50	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Ba	2000	1180	546	551	259	264	271	253	1840	1570	1620	1480
Be	4	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Cd	5	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Ca		209000 B	133000	133000	73200	78100	72600	70900	262000	231000	229000	194000
Cr	100	6.2 B	5 U	5 U	5 U	5 U	5 U	5 U	6.2 B	5 U	5 U	7.6 B
Co		5 U	5 U	5 U	5 U	5 U	5 U	5 U	8 B	5 U	5 U	5 U
Cu		5 U	5 U	5 U	5 U	5 U	5 B	5 U	5 U	5 U	5 U	5 U
Fe	300	5830	3880	3450	676	74.1 B	98.8 B	146	16100	13300	13100	11700
Pb	15	3 U	5.2	3 U	3 U	3 U	3 U	3 U	3 U	4.3	3 U	3 U
Mg		70400 B	46000 B	45400 B	21200	23600 B	20900	22300	125000	111000	110000	103000
Mn	50	1990	1110	1120	53.3	67.3	87.8	122	5620	4100	4080	3550
Hg	2	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Ni		7.3 B	10.2 B	5.6 B	6.9 B	5 U	6.1 B	8.4	18.8 B	7.8 B	6.2 B	9 B
K		8270	6060	6080	4830 B	4730 B	4520 B	4450 B	18500	11300	11600	10700
Se	50	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Ag	100	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Na		612000	283000	278000	54900	66000	62100	64000	435000	435000	442000	393000
Tl	2	10 U	10 U	10 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
V		5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Zn	5000	3510	926	484	124	261	404	266	137	5950	5680	3350

'U' Indicates that the identified element was not detected at the given concentration

'B' Indicates that the concentration of the identified element was below the MDL, but was above the instrument detection limit

Appendix D
Groundwater Monitoring Data

Groundwater monitoring data given in units of ug/L

	MCL	Apr-00	Apr-00	Nov-99	Jan-00	Feb-00	Apr-00
log no.		6201LA	6202LA	12901LA	31001LA	901LA	6701LA
		TAN-37B	TAN-37B	TAN-D2	TAN-D2	TAN-D2	TAN-D2
Analyte		Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered
Al	200	481	792	50 U	50 U	50 U	50 U
Sb	6	10 U	10 U	5 U	10 U	10 U	10 U
As	50	5 U	5 U	5 U	5 U	5.5 B	5 U
Ba	2000	1120	1120	292	253	296	269
Be	4	5 U	5 U	5 U	5 U	5 U	5 U
Cd	5	5 U	5 U	5 U	5 U	5 U	5 U
Ca		175000	175000	73400	78800	80900	79000
Cr	100	5 U	5 U	5 U	5 U	5 U	7.2
Co		5 U	5 U	5 U	5 U	5 U	5 U
Cu		5 U	5 U	5 U	5 U	5 U	5 U
Fe	300	10500	11300	1780	533	2630	1850
Pb	15	3 U	3 U	3 U	3 U	3 U	3 U
Mg		87800	88200	19900	21800 B	23100	22300
Mn	50	3260	3270	270	153	213	193
Hg	2	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Ni		11.3	12.8	5 U	5 U	5 U	5 U
K		9070	9060	4360 B	4060 B	4040 B	3940 B
Se	50	5 U	5 U	5 U	5 U	5 U	5 U
Ag	100	5 U	5 U	5 U	5 U	5 U	5 U
Na		343000	345000	49300	56700	60100	56900
Tl	2	2 U	2 U	2 U	2 U	2 U	2 U
V		5 U	5 U	5 U	5 U	5 U	5 U
Zn	5000	3060	3000	161	396	260	199

'U' Indicates that the identified element was not detected at the given concentration
'B' Indicates that the concentration of the identified element was below the MDL, but was above the instrument detection limit